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THERMODYNAMIC AND TRANSPORT PROPERTIES OF AIR AND ITS PRODUCTS OF COMBUSTION WITH ASTM-A-1 FUEL AND NATURAL GAS AT 20, 30, AND 40 ATMOSPHERES

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16. Abstract

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SUMMARY

The isentropic exponent, molecular weight, viscosity, specific heat at constant pressure, thermal conductivity, Prandtl number, and enthalpy were calculated for air, the combustion products of ASTM-A-1 jet fuel and air, and the combustion products of natural gas and air. The properties were calculated over a temperature range from 300 to 2800 K in 100 K increments and for pressures of 20, 30, and 40 atmospheres. The data for natural gas and ASTM-A-1 were calculated for fuel-air ratios from zero to stoichiometric in 0.01 increments.

INTRODUCTION

An analytical investigation was conducted to determine the thermodynamic and transport properties for air, the combustion products of ASTM-A-1 jet fuel and air, and the combustion products of natural gas and air at the pressures and temperatures encountered in NASA jet engine design studies. Data for these properties were not available in the literature over the full range of interest (e.g., refs. 1 and 2). Accurate values are required for performing jet engine cycle studies and for designing cooling configurations for combustor liners and turbine vanes and blades. Since the gas temperatures of interest are usually too high for the properties to be measured directly, the properties must be calculated.

The properties calculated were the isentropic exponent γ, molecular weight m, viscosity μ, specific heat at constant pressure c_p, thermal conductivity k, Prandtl number Pr, and enthalpy h. The calculations were made for (1) air, (2) ASTM-A-1 jet fuel burned in air, and (3) natural gas burned in air. All properties were calculated for temperatures from 300 to 2800 K at pressures of 20, 30, and 40 atmospheres. The

properties for the combustion products of both ASTM-A-1 and natural gas were determined for fuel-air ratios from 0.01 to stoichiometric.

SYMBOLS

c_p specific heat at constant pressure, cal/(g)(K)

h enthalpy, cal/g

k thermal conductivity, cal/(cm)(sec)(K)

m molecular weight

P pressure, atm

Pr Prandtl number

s entropy, cal/(g)(K)

T temperature, K

γ isentropic exponent, $(\partial \ln P/\partial \ln \rho)_s$

μ viscosity, g/(cm)(sec)

THERMODYNAMIC AND TRANSPORT PROPERTY CALCULATIONS PROGRAM

The program used to calculate the thermodynamic and transport properties is described in references 3 and 4. It is a program which combines the thermodynamic chemical equilibrium compositions program (ref. 5) with additional routines to calculate the transport properties. Condensed species, as well as gaseous species, are considered when obtaining the equilibrium composition and when calculating the thermodynamic properties. However, only the gaseous species are used when calculating the transport properties.

Because of storage limitations, the maximum allowable number of species is 100 and the maximum number of chemical elements is 10 for the thermodynamic property calculations. However, in computing the transport properties, the equilibrium composition obtained from the thermodynamic calculations is searched for the 20 gaseous species with the largest concentrations. All gaseous species with equilibrium mole fractions less than 10^{-7} are omitted.

The transport cross-section data used in the calculations are the data included with the program described in reference 4. Most of these data came from references 3 and 6 to 9. Rotational relaxation effects are included in calculating the thermal conductivity. Input data used in the transport property calculations are slightly different than the data

used in calculating the properties of reference 1. However, the differences are generally small and change the results by only a few percent. In order to see the actual differences used in the input, the reader is referred to reference 4.

The compositions assumed for air, ASTM-A-1, and natural gas are given in appendix A.

THERMODYNAMIC AND TRANSPORT PROPERTIES

Calculations of thermodynamic and transport properties were made for air, ASTM-A-1 burned in air, and natural gas burned in air at temperatures from 300 to 2800 K in 100 K increments; at pressures of 20, 30, and 40 atmospheres; and at fuel-air ratios from 0.01 to stoichiometric in 0.01 increments. The results of these calculations are presented in tables I to IX. Conversion units for viscosity, thermal conductivity, specific heat at constant pressure, and enthalpy are given in appendix B. Reference enthalpies are the same as those given in reference 5; that is, the enthalpy of the elements in their most stable form is assumed to be zero at 298.15 K.

Air

The thermodynamic and transport properties γ, m, μ, c_p, k, Pr, and h of air at pressures of 20, 30, and 40 atmospheres are given in tables I to III, respectively. The data show that the isentropic exponent decreases with increasing temperature, whereas the viscosity, specific heat at constant pressure, thermal conductivity, and enthalpy increase with increasing temperature. The molecular weight and Prandtl number remain nearly constant until dissociation effects become apparent at approximately 2000 K. Furthermore, since the composition remains constant, increasing the pressure from 20 to 40 atmospheres has essentially no effect on the thermodynamic and transport properties at temperatures below approximately 2000 K. The difference in the viscosity of air at 20 and 40 atmospheres is negligible over the entire range of temperatures presented. Above 2000 K, γ, m, and Pr increase with increasing pressure, whereas c_p, k, and h decrease with increasing pressure. The greatest effect of pressure occurs in the c_p, k, and Pr data.

Combustion Products of ASTM-A-1 and Air

The thermodynamic and transport properties of the combustion products of ASTM-A-1 are given in table IV for fuel-air ratios from 0.01 to stoichiometric at a pressure of

20 atmospheres. The trend of the properties with temperature is the same as that described for air. The effect of fuel-air ratio varies with the particular property being considered. That is, the isentropic exponent and enthalpy decrease with increasing fuel-air ratio, whereas the specific heat at constant pressure and thermal conductivity increase with increasing fuel-air ratio. At temperatures above approximately 1700 K, the molecular weight decreases with increasing fuel-air ratio. Below 1700 K, the molecular weight is essentially independent of fuel-air ratio over the range of fuel-air ratios investigated. The viscosity increases with increasing fuel-air ratio at temperatures above approximately 1400 K, whereas the opposite trend is observed below 1400 K. The Prandtl number increases with increasing fuel-air ratio below about 1500 K and decreases at temperatures greater than 1500 K. The properties most affected by fuel-air ratio are specific heat at constant pressure, thermal conductivity, and enthalpy.

This behavior can be qualitatively explained in terms of the change in the equilibrium combustion product composition with fuel-air ratio changes. At the lower temperatures the properties change solely because of the greater percentage of combustion products in the mixture. This affects all the properties to some degree. However, at higher temperatures another effect becomes important, dissociation. Chemical reactions, and in particular dissociation, have a very pronounced effect on some properties, especially the specific heat at constant pressure and thermal conductivity. There can be a very large enhancement in the value of these properties over that for nondissociating species. See reference 4 for a more detailed explanation and reference 3 for figures showing the effects of varying temperature, pressure, and fuel-oxidant mixture ratios over a large range of conditions.

Similar data for the properties at 30 and 40 atmospheres are given in tables V and VI, respectively. The effect of fuel-air ratio on the property data at 30 and 40 atmospheres is the same as that presented for a pressure of 20 atmospheres. All property variations with pressure are similar to those discussed previously for air, with the effect of pressure becoming noticeable above approximately 1700 K.

Combustion Products of Natural Gas and Air

The properties of the combustion products of natural gas are presented in table VII for fuel-air ratios from 0.01 to stoichiometric at a pressure of 20 atmospheres. The variation of property data with fuel-air ratio and temperature is similar to that discussed previously for ASTM-A-1. The only significant difference is that the molecular weight of the combustion products of natural gas is more sensitive to fuel-air ratio than is the molecular weight of the combustion products of ASTM-A-1. The reason is that the hydrogen/carbon ratio of natural gas is higher than that of ASTM-A-1.

Property data for the combustion products of natural gas at pressures of 30 and 40 atmospheres are given in tables VIII and IX, respectively. All property variations with pressure are similar to those for air and the combustion products of ASTM-A-1. Comparing tables IV to IX shows that at any given temperature, pressure, and fuel-air ratio, γ, m, Pr, and h for the combustion products of natural gas are in general lower than the corresponding values for the combustion products of ASTM-A-1. However, the reverse is true for c_p and k over the range of temperature, pressure, and fuel-air ratio investigated. The viscosity at any given temperature and pressure is essentially the same for the combustion products of both natural gas and ASTM-A-1.

CONCLUDING REMARKS

The isentropic exponent, molecular weight, viscosity, specific heat at constant pressure, thermal conductivity, Prandtl number and enthalpy were calculated for air, the combustion products of ASTM-A-1 and air, and the combustion products of natural gas and air. These properties were calculated for temperatures from 300 to 2800 K and for pressures of 20, 30, and 40 atmospheres. The data for ASTM-A-1 and natural gas were determined for fuel-air ratios from 0.01 to stoichiometric.

The theoretical data presented herein are for the combustion products of air and the fuels defined in appendix A. However, it is estimated that the difference between calculated thermodynamic and transport properties of the combustion products of ASTM-A-1 burned in air and the properties of any of the typical JP fuels burned in air will be less than 0.5 percent for the same equivalence ratio. Likewise, errors of less than 0.5 percent will be introduced if the thermodynamic and transport properties of the combustion products of natural gas are used for the properties of the combustion products of methane or any nominal natural gas composition.

The effect of pressure on the theoretical properties is negligible for temperatures less than 2000 K for air and for temperatures less than approximately 1700 K for the combustion products of ASTM-A-1 or natural gas since the amount of dissociation does not become a significant factor until these temperatures are reached. The properties most affected by fuel-air ratio were specific heat at constant pressure, thermal conductivity, and enthalpy. The specific heat at constant pressure, thermal conductivity, and Prandtl number were the most sensitive to pressure.

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501-24.

APPENDIX A

COMPOSITIONS OF AIR, ASTM-A-1, AND NATURAL GAS

The following compositions were assumed for air, ASTM-A-1, and natural gas. The composition of air is given by the following formula: $C_{0.00030}N_{1.56176}O_{0.41959}Ar_{0.00932}$. ASTM-A-1 jet fuel was assumed to have the composition $CH_{1.9185}$. Natural gas was assumed to consist of the following components:

Component	Composition, wt. %
Nitrogen, N_2	2.648
Methane, CH_4	87.474
Carbon dioxide, CO_2	1.181
Ethane, C_2H_6	6.332
Propane, C_3H_8	1.621
Butane, C_4H_{10}	.576
Pentane, C_5H_{12}	.168

APPENDIX B

CONVERSION UNITS FOR VISCOSITY, THERMAL CONDUCTIVITY, SPECIFIC HEAT AT CONSTANT PRESSURE, AND ENTHALPY

The factors for converting viscosity, thermal conductivity, specific heat at constant pressure, and enthalpy from cgs units to SI and English units are the following:

Viscosity:

$$1 \frac{g}{(cm)(sec)} = 0.1 \frac{(N)(sec)}{m^2}$$

$$= 6.72 \times 10^{-2} \frac{lbm}{(ft)(sec)}$$

$$= 241.9 \frac{lbm}{(ft)(hr)}$$

$$= 2.089 \times 10^{-3} \frac{(lbf)(sec)}{ft^2}$$

Thermal conductivity:

$$1 \frac{cal}{(cm)(sec)(K)} = 418.4 \frac{W}{(m)(K)}$$

$$= 0.8064 \frac{Btu}{(ft)^2(sec)(^oF/in.)}$$

$$= 6.72 \times 10^{-2} \frac{Btu}{(ft^2)(sec)(^oF/ft)}$$

$$= 241.9 \frac{Btu}{(ft)^2(hr)(^oF/ft)}$$

Specific heat at constant pressure:

$$1 \frac{\text{cal}}{(\text{g})(\text{K})} = 4.184 \frac{\text{J}}{(\text{g})(\text{K})}$$

$$= 1 \frac{\text{Btu}}{(\text{lbm})(^{\circ}\text{F})}$$

Enthalpy:

$$1 \frac{\text{cal}}{\text{g}} = 4.184 \frac{\text{J}}{\text{g}}$$

$$= 1.8 \frac{\text{Btu}}{\text{lbm}}$$

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TABLE I. - THERMODYNAMIC AND TRANSPORT PROPERTIES OF AIR AT 20 ATMOSPHERES

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2309	28.890	821×10^{-6}	0.3850	473×10^{-6}	0.669	747.0
2700	1.2374	28.915	800	.3707	439	.676	709.2
2600	1.2437	28.933	779	.3588	409	.683	672.7
2500	1.2498	28.945	758	.3488	384	.688	637.4
2400	1.2556	28.953	736	.3404	362	.692	602.9
2300	1.2612	28.958	715	.3332	343	.696	569.3
2200	1.2666	28.961	694	.3270	325	.698	536.2
2100	1.2719	28.963	672	.3214	309	.699	503.8
2000	1.2772	28.964	651	.3163	294	.700	471.9
1900	1.2825	28.965	629	.3115	280	.701	440.6
1800	1.2879	↓	607	.3070	266	.702	409.6
1700	1.2933	↓	585	.3025	252	.702	379.2
1600	1.2989	↓	563	.2981	239	.703	349.1
1500	1.3045	↓	540	.2939	226	.703	319.5
1400	1.3103	↓	517	.2897	213	.704	290.3
1300	1.3162	↓	494	.2855	200	.704	261.6
1200	1.3224	↓	470	.2814	188	.705	233.2
1100	1.3288	↓	445	.2773	175	.705	205.3
1000	1.3356	↓	419	.2730	162	.705	177.8
900	1.3439	28.964	391	.2681	148	.706	150.7
800	1.3537	↓	362	.2626	135	↓	124.2
700	1.3646	↓	331	.2568	121	↓	98.2
600	1.3759	↓	299	.2511	106	↓	72.8
500	1.3865	↓	265	.2461	92	↓	48.0
400	1.3951	↓	227	.2422	78	↓	23.6
300	1.4000	↓	184	.2401	63	↓	-.5

TABLE II. - THERMODYNAMIC AND TRANSPORT PROPERTIES OF AIR AT 30 ATMOSPHERES

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2340	28.904	821×10^{-6}	0.3773	460×10^{-6}	0.674	745.0
2700	1.2399	28.924	800	.3652	430	.680	707.9
2600	1.2456	28.939	779	.3548	403	.686	671.9
2500	1.2512	28.949	758	.3462	380	.690	636.8
2400	1.2566	28.956	736	.3387	359	.694	602.6
2300	1.2619	28.960	715	.3321	341	.696	569.1
2200	1.2671	28.962	694	.3263	324	.698	536.1
2100	1.2722	28.964	672	.3211	309	.699	503.8
2000	1.2773	28.965	651	.3161	294	.700	471.9
1900	1.2826	↓	629	.3115	280	.701	440.5
1800	1.2879	↓	607	.3069	266	.702	409.6
1700	1.2933	↓	585	.3025	252	.702	379.2
1600	1.2988	↓	563	.2981	239	.703	349.1
1500	1.3045	↓	540	.2939	226	.703	319.5
1400	1.3103	↓	517	.2897	213	.704	290.3
1300	1.3162	↓	494	.2855	200	.704	261.6
1200	1.3223	↓	470	.2814	188	.705	233.2
1100	1.3288	↓	445	.2773	175	.705	205.3
1000	1.3356	↓	419	.2730	162	.705	177.8
900	1.3439	28.964	391	.2681	148	.706	150.7
800	1.3537	↓	362	.2626	135	↓	124.2
700	1.3646	↓	331	.2568	121	↓	98.2
600	1.3759	↓	299	.2511	106	↓	72.8
500	1.3865	↓	265	.2461	92	↓	48.0
400	1.3951	↓	227	.2422	78	↓	23.6
300	1.4000	↓	184	.2401	63	↓	-.5

TABLE III. - THERMODYNAMIC AND TRANSPORT PROPERTIES OF AIR AT 40 ATMOSPHERES

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2360	28.913	821×10^{-6}	0.3727	452×10^{-6}	0.677	743.8
2700	1.2414	28.930	800	.3619	424	.683	707.1
2600	1.2468	28.943	779	.3526	399	.688	671.4
2500	1.2521	28.951	758	.3446	377	.692	636.5
2400	1.2573	28.957	736	.3376	358	.695	602.4
2300	1.2623	28.961	715	.3315	340	.697	569.0
2200	1.2673	28.963	694	.3260	324	.699	536.1
2100	1.2724	28.964	672	.3209	308	.700	503.8
2000	1.2774	28.965	651	.3160	294	.700	471.9
1900	1.2826	↓	629	.3114	279	.701	440.5
1800	1.2879		607	.3069	266	.702	409.6
1700	1.2933		585	.3025	252	.702	379.2
1600	1.2988		563	.2981	239	.703	349.1
1500	1.3045		540	.2939	226	.703	319.5
1400	1.3103		517	.2897	213	.704	290.4
1300	1.3162		494	.2855	200	.704	261.6
1200	1.3223		470	.2814	188	.705	233.2
1100	1.3288		445	.2773	175	.705	205.3
1000	1.3356		419	.2730	162	.705	177.8
900	1.3439		391	.2681	148	.706	150.7
800	1.3537	28.964	362	.2626	135	↓	124.2
700	1.3646	↓	331	.2568	121		98.2
600	1.3759		299	.2511	106		72.8
500	1.3865		265	.2461	92		48.0
400	1.3951		227	.2422	78		23.6
300	1.4000	↓	184	.2401	63	↓	-.5

TABLE IV. - THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 20 ATMOSPHERES

(a) Fuel-air ratio, 0.01

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2154	28.823	826×10^{-6}	0.4220	546×10^{-6}	0.639	663.2
2700	1.2228	28.866	805	.4010	494	.653	622.1
2600	1.2303	28.897	784	.3833	451	.666	582.9
2500	1.2377	28.920	762	.3685	416	.675	545.3
2400	1.2447	28.936	741	.3563	386	.683	509.1
2300	1.2514	28.947	719	.3461	361	.689	474.0
2200	1.2578	28.955	698	.3375	340	.693	439.8
2100	1.2639	28.959	676	.3303	321	.696	406.4
2000	1.2697	28.962	654	.3239	304	.698	373.7
1900	1.2754	28.964	632	.3183	288	.699	341.6
1800	1.2809	28.965	610	.3131	273	.700	310.1
1700	1.2865	28.965	588	.3082	258	.701	279.0
1600	1.2920	28.966	565	.3036	244	.702	248.4
1500	1.2976	↓	542	.2991	231	.703	218.3
1400	1.3033	↓	519	.2948	217	.704	188.6
1300	1.3091	↓	495	.2905	204	.704	159.3
1200	1.3152	↓	470	.2863	191	.705	130.5
1100	1.3216	↓	445	.2819	178	.706	102.1
1000	1.3285	↓	419	.2775	164	.706	74.1
900	1.3368	↓	391	.2723	150	.707	46.6
800	1.3466	↓	361	.2665	136	.708	19.6
700	1.3576	↓	331	.2605	122	.708	-6.7
600	1.3690	↓	298	.2545	107	.708	-32.5
500	1.3800	↓	263	.2492	92	.709	-57.6
400	1.3892	↓	225	.2449	78	.709	-82.3
[a]300	1.3328	29.497	183	.2398	62	.706	-113.2

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IV. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 20 ATMOSPHERES

(b) Fuel-air ratio, 0.02

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2055	28.781	831×10^{-6}	0.4497	596×10^{-6}	0.626	576.6
2700	1.2137	28.837	809	.4229	532	.643	533.0
2600	1.2220	28.878	788	.4003	479	.658	491.8
2500	1.2301	28.908	766	.3817	437	.670	452.8
2400	1.2379	28.928	745	.3667	402	.679	415.4
2300	1.2452	28.943	723	.3545	374	.686	379.3
2200	1.2519	28.952	701	.3446	350	.691	344.4
2100	1.2582	28.958	679	.3365	329	.694	310.4
2000	1.2641	28.962	657	.3296	311	.696	277.1
1900	1.2697	28.964	635	.3236	294	.698	244.4
1800	1.2752	28.965	612	.3183	278	.700	212.3
1700	1.2805	28.966	589	.3133	263	.701	180.7
1600	1.2858	28.967	566	.3087	249	.702	149.6
1500	1.2912	↓	543	.3042	235	.703	119.0
1400	1.2967	↓	519	.2998	221	.704	88.8
1300	1.3025	↓	495	.2954	208	.705	59.0
1200	1.3084	↓	470	.2910	194	.706	29.7
1100	1.3148	↓	445	.2865	180	.706	.8
1000	1.3218	↓	418	.2818	167	.707	-27.6
900	1.3301	↓	390	.2764	152	.708	-55.5
800	1.3399	↓	360	.2704	137	.709	-82.8
700	1.3509	↓	329	.2641	122	.710	-109.6
600	1.3625	↓	296	.2579	108	.711	-135.7
500	1.3737	↓	261	.2522	93	.712	-161.2
400	1.3836	↓	222	.2474	77	.713	-186.1
[a]300	1.3124	30.092	183	.2393	62	.706	-224.3

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IV. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 20 ATMOSPHERES

(c) Fuel-air ratio, 0.03

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1970	28.739	834×10^{-6}	0.4778	646×10^{-6}	0.617	491.4
2700	1.2056	28.808	813	.4448	569	.635	445.3
2600	1.2146	28.859	791	.4171	506	.652	402.2
2500	1.2236	28.896	770	.3944	456	.665	361.7
2400	1.2320	28.922	748	.3764	417	.675	323.2
2300	1.2398	28.939	726	.3622	385	.683	286.3
2200	1.2469	28.950	704	.3511	359	.689	250.6
2100	1.2533	28.957	682	.3421	337	.693	216.0
2000	1.2592	28.962	659	.3348	317	.696	182.1
1900	1.2647	28.965	637	.3286	300	.698	149.0
1800	1.2699	28.966	614	.3232	284	.699	116.4
1700	1.2751	28.967	591	.3182	268	.701	84.3
1600	1.2802	28.967	567	.3135	254	.702	52.7
1500	1.2853	28.968	544	.3090	239	.703	21.6
1400	1.2907	↓	520	.3046	225	.704	-9.1
1300	1.2962		495	.3002	211	.705	-39.3
1200	1.3021		470	.2956	197	.706	-69.1
1100	1.3085		444	.2910	183	.707	-98.4
1000	1.3154		417	.2861	169	.709	-127.3
900	1.3238		389	.2804	154	.710	-155.6
800	1.3337		359	.2742	139	.711	-183.4
700	1.3446		328	.2676	123	.712	-210.4
600	1.3563		295	.2611	108	.713	-236.9
500	1.3678		259	.2551	92	.715	-262.7
400	1.3783		220	.2499	77	.717	-287.9
[a]300	1.2940	30.699	182	.2389	62	.706	-333.2

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IV. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 20 ATMOSPHERES

(d) Fuel-air ratio, 0.04

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1889	28.690	837×10^{-6}	0.5094	701×10^{-6}	0.609	408.6
2700	1.1978	28.775	816	.4696	610	.628	359.7
2600	1.2074	28.838	794	.4358	536	.646	314.4
2500	1.2172	28.883	772	.4082	477	.660	272.3
2400	1.2264	28.914	750	.3866	432	.672	232.6
2300	1.2348	28.935	728	.3699	396	.681	194.8
2200	1.2423	28.949	706	.3572	367	.687	158.5
2100	1.2489	28.957	684	.3474	343	.692	123.3
2000	1.2548	28.962	661	.3396	323	.695	89.0
1900	1.2602	28.965	638	.3332	305	.697	55.3
1800	1.2652	28.967	615	.3278	288	.699	22.3
1700	1.2701	28.968	592	.3228	273	.700	-10.3
1600	1.2749	28.968	568	.3182	258	.702	-42.3
1500	1.2799	28.969	544	.3137	243	.703	-73.9
1400	1.2850	↓	520	.3093	228	.704	-105.0
1300	1.2904	↓	495	.3048	214	.705	-135.8
1200	1.2962	↓	470	.3002	199	.707	-166.0
1100	1.3025	↓	444	.2954	185	.708	-195.8
1000	1.3095	↓	416	.2903	170	.710	-225.1
900	1.3179	↓	388	.2844	155	.711	-253.8
800	1.3277	↓	358	.2779	140	.713	-281.9
700	1.3387	↓	326	.2711	124	.714	-309.4
600	1.3504	↓	293	.2644	108	.716	-336.2
500	1.3622	↓	257	.2580	92	.718	-362.3
400	1.3732	↓	218	.2524	76	.720	-387.8
[a]300	1.2773	31.319	182	.2384	61	.706	-440.0

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IV. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 20 ATMOSPHERES

(e) Fuel-air ratio, 0.05

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1805	28.625	840×10^{-6}	0.5483	765×10^{-6}	0.601	329.7
2700	1.1894	28.730	818	.5012	660	.621	277.3
2600	1.1995	28.809	797	.4600	573	.639	229.3
2500	1.2100	28.865	775	.4258	504	.655	185.1
2400	1.2203	28.904	753	.3990	450	.668	143.9
2300	1.2297	28.930	730	.3787	408	.678	105.1
2200	1.2379	28.946	708	.3636	376	.685	68.0
2100	1.2449	28.956	685	.3525	350	.690	32.2
2000	1.2509	28.962	662	.3441	328	.694	-2.6
1900	1.2562	28.966	639	.3375	310	.697	-36.7
1800	1.2610	28.968	616	.3320	293	.699	-70.1
1700	1.2656	28.969	592	.3271	277	.700	-103.1
1600	1.2702	28.969	568	.3226	261	.702	-135.6
1500	1.2748	28.970	544	.3182	246	.703	-167.6
1400	1.2797	↓	519	.3138	231	.705	-199.2
1300	1.2850		494	.3093	217	.706	-230.4
1200	1.2907		469	.3046	202	.707	-261.1
1100	1.2969		442	.2996	187	.709	-291.3
1000	1.3038		415	.2943	172	.711	-321.0
900	1.3122		386	.2883	156	.712	-350.1
800	1.3221		356	.2816	140	.714	-378.6
700	1.3331		324	.2745	124	.716	-406.4
600	1.3449		291	.2675	108	.718	-433.5
500	1.3568		255	.2608	92	.721	-459.9
400	1.3683	↓	215	.2548	76	.724	-485.7
[a]300	1.2621	31.952	181	.2379	61	.707	-544.8

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IV. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 20 ATMOSPHERES

(f) Fuel-air ratio, 0.06

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1719	28.516	841×10^{-6}	0.5975	842×10^{-6}	0.597	258.9
2700	1.1795	28.648	820	.5465	728	.616	201.7
2600	1.1890	28.752	798	.4984	629	.633	149.5
2500	1.1999	28.829	776	.4557	546	.648	101.8
2400	1.2115	28.883	754	.4203	479	.662	58.1
2300	1.2227	28.918	732	.3929	427	.673	17.5
2200	1.2325	28.941	709	.3728	388	.682	-20.8
2100	1.2407	28.954	686	.3586	358	.688	-57.3
2000	1.2473	28.962	663	.3486	334	.693	-92.6
1900	1.2527	28.966	640	.3413	314	.696	-127.1
1800	1.2574	28.969	616	.3357	296	.698	-160.9
1700	1.2617	28.970	592	.3310	280	.700	-194.3
1600	1.2659	28.970	568	.3266	265	.702	-227.1
1500	1.2703	28.970	544	.3224	249	.703	-259.6
1400	1.2749	28.971	519	.3181	234	.705	-291.6
1300	1.2799		494	.3136	219	.706	-323.2
1200	1.2855		468	.3089	204	.708	-354.3
1100	1.2916		441	.3038	189	.710	-385.0
1000	1.2985		414	.2983	173	.712	-415.1
900	1.3069		385	.2921	157	.714	-444.6
800	1.3167		354	.2852	141	.716	-473.5
700	1.3277		322	.2779	125	.718	-501.6
600	1.3396		288	.2706	108	.721	-529.1
500	1.3518		252	.2636	92	.724	-555.8
400	1.3637		212	.2572	75	.728	-581.8
[a]300	1.2482	32.598	180	.2374	61	.707	-647.6

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IV. - Concluded. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 20 ATMOSPHERES

(g) Fuel-air ratio, 0.06817 (stoichiometric)

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1675	28.341	842×10^{-6}	0.6293	883×10^{-6}	0.600	215.5
2700	1.1733	28.491	820	.5821	771	.620	154.9
2600	1.1805	28.615	799	.5373	674	.637	99.0
2500	1.1889	28.715	777	.4961	592	.651	47.3
2400	1.1984	28.792	755	.4597	524	.663	-.4
2300	1.2085	28.851	732	.4284	467	.672	-44.8
2200	1.2186	28.893	710	.4025	420	.679	-86.3
2100	1.2284	28.923	687	.3816	382	.685	-125.4
2000	1.2372	28.943	663	.3653	351	.690	-162.7
1900	1.2450	28.955	640	.3529	326	.693	-198.6
1800	1.2517	28.963	616	.3435	304	.696	-233.4
1700	1.2573	28.967	592	.3363	285	.699	-267.4
1600	1.2623	28.970	568	.3306	268	.701	-300.7
1500	1.2669	28.971	543	.3258	252	.703	-333.6
1400	1.2715	↓	518	.3213	236	.705	-365.9
1300	1.2764		493	.3168	221	.707	-397.8
1200	1.2817		467	.3121	206	.709	-429.3
1100	1.2877		440	.3070	190	.711	-460.2
1000	1.2945		412	.3015	174	.713	-490.6
900	1.3028		383	.2951	158	.715	-520.5
800	1.3126		352	.2880	142	.717	-549.6
700	1.3236		320	.2806	125	.720	-578.1
600	1.3354		286	.2731	108	.723	-605.8
500	1.3478	↓	250	.2658	91	.726	-632.7
[a]400	1.1906	29.308	211	.2577	75	.729	-662.7
[a]300	1.2376	33.136	180	.2369	60	.707	-730.1

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE V. - THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 30 ATMOSPHERES

(a) Fuel-air ratio, 0.01

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2194	28.846	826×10^{-6}	0.4100	523×10^{-6}	0.648	659.8
2700	1.2263	28.881	805	.3921	478	.661	619.7
2600	1.2332	28.908	784	.3768	440	.671	581.3
2500	1.2399	28.927	762	.3639	408	.679	544.2
2400	1.2464	28.941	741	.3531	382	.686	508.4
2300	1.2527	28.950	719	.3440	358	.690	473.6
2200	1.2587	28.956	698	.3362	338	.694	439.6
2100	1.2645	28.960	676	.3294	320	.696	406.3
2000	1.2701	28.963	654	.3234	303	.698	373.6
1900	1.2756	28.964	632	.3180	287	.699	341.6
1800	1.2811	28.965	610	.3129	272	.701	310.0
1700	1.2865	28.966	588	.3081	258	.701	279.0
1600	1.2920	↓	565	.3036	244	.702	248.4
1500	1.2976	↓	542	.2991	231	.703	218.3
1400	1.3033	↓	519	.2948	217	.704	188.6
1300	1.3091	↓	495	.2905	204	.704	159.3
1200	1.3152	↓	470	.2863	191	.705	130.5
1100	1.3216	↓	445	.2819	178	.706	102.1
1000	1.3285	↓	419	.2775	164	.706	74.1
900	1.3368	↓	391	.2723	150	.707	46.6
800	1.3466	↓	361	.2665	136	.708	19.6
700	1.3576	↓	331	.2605	122	.708	-6.7
600	1.3690	↓	298	.2545	107	.708	-32.5
500	1.3799	↓	263	.2492	92	.709	-57.6
400	1.3892	↓	225	.2449	78	.709	-82.3
[a]300	1.3440	29.514	183	.2398	62	.706	-113.4

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE V. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 30 ATMOSPHERES

(b) Fuel-air ratio, 0.02

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2101	28.810	831×10^{-6}	0.4342	566×10^{-6}	0.637	572.1
2700	1.2177	28.857	809	.4111	510	.652	529.9
2600	1.2254	28.891	788	.3917	465	.664	489.7
2500	1.2329	28.916	766	.3757	427	.674	451.4
2400	1.2400	28.934	745	.3626	396	.682	414.5
2300	1.2467	28.946	723	.3518	370	.688	378.8
2200	1.2530	28.954	701	.3429	347	.692	344.1
2100	1.2589	28.959	679	.3354	328	.695	310.2
2000	1.2646	28.963	657	.3290	310	.697	276.9
1900	1.2700	28.965	635	.3233	294	.699	244.3
1800	1.2753	28.966	612	.3181	278	.700	212.3
1700	1.2806	28.966	589	.3132	263	.701	180.7
1600	1.2859	28.967	566	.3086	249	.702	149.6
1500	1.2913	↓	543	.3041	235	.703	119.0
1400	1.2968	↓	519	.2998	221	.704	88.8
1300	1.3024	↓	495	.2954	208	.705	59.0
1200	1.3084	↓	470	.2910	194	.706	29.7
1100	1.3148	↓	445	.2865	180	.706	.8
1000	1.3217	↓	418	.2818	167	.707	-27.6
900	1.3301	↓	390	.2764	152	.708	-55.5
800	1.3399	↓	360	.2704	137	.709	-82.8
700	1.3509	↓	329	.2641	122	.710	-109.6
600	1.3625	↓	296	.2579	108	.711	-135.7
500	1.3737	↓	261	.2522	93	.712	-161.2
400	1.3836	↓	222	.2474	77	.713	-186.1
[a]300	1.3219	30.110	183	.2393	62	.706	-224.5

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE V. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 30 ATMOSPHERES

(c) Fuel-air ratio, 0.03

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2020	28.774	834×10^{-6}	0.4585	608×10^{-6}	0.629	485.8
2700	1.2102	28.833	813	.4301	542	.645	441.4
2600	1.2186	28.876	791	.4064	488	.659	399.6
2500	1.2268	28.907	770	.3869	444	.670	360.0
2400	1.2345	28.928	748	.3713	409	.679	322.1
2300	1.2416	28.943	726	.3589	380	.686	285.6
2200	1.2481	28.953	704	.3490	356	.690	250.2
2100	1.2541	28.959	682	.3408	335	.694	215.8
2000	1.2597	28.963	659	.3341	316	.696	182.0
1900	1.2650	28.965	637	.3282	299	.698	148.9
1800	1.2701	28.966	614	.3229	283	.699	116.4
1700	1.2752	28.967	591	.3181	268	.701	84.3
1600	1.2802	28.968	567	.3135	253	.702	52.7
1500	1.2854	↓	544	.3090	239	.703	21.6
1400	1.2907	↓	520	.3046	225	.704	-9.1
1300	1.2962	↓	495	.3002	211	.705	-39.3
1200	1.3021	↓	470	.2956	197	.706	-69.1
1100	1.3085	↓	444	.2910	183	.707	-98.4
1000	1.3154	↓	417	.2861	169	.709	-127.3
900	1.3238	↓	389	.2805	154	.710	-155.6
800	1.3337	↓	359	.2742	139	.711	-183.4
700	1.3446	↓	328	.2676	123	.712	-210.4
600	1.3563	↓	295	.2611	108	.713	-236.9
500	1.3678	↓	259	.2551	92	.715	-262.7
400	1.3783	↓	220	.2499	77	.717	-287.9
[a]300	1.3021	30.717	182	.2388	62	.706	-333.4

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE V. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 30 ATMOSPHERES

(d) Fuel-air ratio, 0.04

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1942	28.734	837×10^{-6}	0.4860	655×10^{-6}	0.621	401.7
2700	1.2029	28.805	816	.4515	577	.639	354.9
2600	1.2119	28.858	794	.4224	513	.654	311.2
2500	1.2209	28.896	772	.3989	462	.666	270.2
2400	1.2293	28.922	751	.3803	422	.676	231.3
2300	1.2369	28.940	728	.3658	390	.683	194.0
2200	1.2438	28.951	706	.3546	364	.689	158.0
2100	1.2499	28.959	684	.3458	341	.693	123.0
2000	1.2554	28.963	661	.3387	322	.695	88.8
1900	1.2605	28.966	638	.3327	304	.697	55.2
1800	1.2654	28.967	615	.3275	288	.699	22.2
1700	1.2702	28.968	592	.3227	273	.701	-10.3
1600	1.2750	28.968	568	.3181	258	.702	-42.3
1500	1.2799	28.969	544	.3137	243	.703	-73.9
1400	1.2850	↓	520	.3093	228	.704	-105.0
1300	1.2904		495	.3048	214	.705	-135.8
1200	1.2962		470	.3002	199	.707	-166.0
1100	1.3025		444	.2954	185	.708	-195.8
1000	1.3095		416	.2903	170	.710	-225.1
900	1.3179		388	.2844	155	.711	-253.8
800	1.3277		358	.2779	140	.713	-281.9
700	1.3387		326	.2711	124	.714	-309.4
600	1.3504		293	.2644	108	.716	-336.2
500	1.3622		257	.2580	92	.718	-362.3
400	1.3732	↓	218	.2524	76	.720	-387.8
[a]300	1.2842	31.337	182	.2383	61	.706	-440.2

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE V. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 30 ATMOSPHERES

(e) Fuel-air ratio, 0.05

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1859	28.678	840×10^{-6}	0.5205	712×10^{-6}	0.614	321.2
2700	1.1948	28.767	819	.4790	620	.632	271.3
2600	1.2045	28.834	797	.4431	545	.648	225.3
2500	1.2144	28.881	775	.4139	485	.662	182.5
2400	1.2238	28.914	753	.3909	437	.673	142.3
2300	1.2323	28.936	730	.3735	401	.681	104.1
2200	1.2397	28.950	708	.3604	371	.687	67.4
2100	1.2460	28.958	685	.3506	347	.692	31.9
2000	1.2516	28.963	662	.3430	327	.695	-2.8
1900	1.2566	28.966	639	.3369	309	.697	-36.7
1800	1.2612	28.968	616	.3317	292	.699	-70.2
1700	1.2657	28.969	592	.3270	276	.700	-103.1
1600	1.2702	28.969	568	.3225	261	.702	-135.6
1500	1.2749	28.970	544	.3182	246	.703	-167.6
1400	1.2798	↓	519	.3138	231	.705	-199.2
1300	1.2850	↓	494	.3093	217	.706	-230.4
1200	1.2906	↓	469	.3046	202	.707	-261.1
1100	1.2969	↓	442	.2996	187	.709	-291.3
1000	1.3038	↓	415	.2943	172	.711	-321.0
900	1.3122	↓	386	.2883	156	.712	-350.1
800	1.3221	↓	356	.2816	140	.714	-378.6
700	1.3331	↓	324	.2745	124	.716	-406.4
600	1.3449	↓	291	.2675	108	.718	-433.5
500	1.3569	↓	255	.2608	92	.721	-459.9
[a]400	1.2029	29.509	217	.2525	76	.721	-491.7
[a]300	1.2681	31.970	181	.2378	61	.706	-545.0

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE V. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 30 ATMOSPHERES

(f) Fuel-air ratio, 0.06

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1768	28.581	842×10^{-6}	0.5668	783×10^{-6}	0.609	248.2
2700	1.1847	28.696	820	.5204	682	.626	193.8
2600	1.1943	28.786	799	.4773	594	.641	144.0
2500	1.2050	28.851	777	.4397	521	.655	98.2
2400	1.2159	28.897	754	.4090	463	.667	55.8
2300	1.2261	28.927	732	.3855	417	.677	16.1
2200	1.2349	28.946	709	.3683	382	.684	-21.5
2100	1.2422	28.957	686	.3560	354	.690	-57.7
2000	1.2482	28.963	663	.3472	332	.694	-92.8
1900	1.2532	28.967	640	.3406	313	.696	-127.2
1800	1.2576	28.969	616	.3354	296	.699	-161.0
1700	1.2618	28.970	592	.3308	280	.700	-194.3
1600	1.2660	28.970	568	.3266	264	.702	-227.2
1500	1.2703	28.971	544	.3224	249	.703	-259.6
1400	1.2749	↓	519	.3181	234	.705	-291.6
1300	1.2799	↓	494	.3136	219	.706	-323.2
1200	1.2855	↓	468	.3089	204	.708	-354.3
1100	1.2916	↓	441	.3038	189	.710	-385.0
1000	1.2985	↓	414	.2984	173	.712	-415.1
900	1.3069	↓	385	.2921	157	.714	-444.6
800	1.3167	↓	354	.2852	141	.716	-473.5
700	1.3277	↓	322	.2779	125	.718	-501.6
600	1.3396	↓	288	.2706	108	.721	-529.1
500	1.3518	↓	252	.2636	92	.724	-555.8
[a]400	1.1980	30.106	216	.2525	75	.722	-594.2
[a]300	1.2533	32.616	180	.2373	61	.707	-647.8

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE V. - Concluded. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 30 ATMOSPHERES

(g) Fuel-air ratio, 0.06817 (stoichiometric)

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1718	28.414	842×10^{-6}	0.5995	824×10^{-6}	0.613	203.4
2700	1.1777	28.547	821	.5565	725	.630	145.6
2600	1.1850	28.657	799	.5161	640	.645	92.0
2500	1.1934	28.745	777	.4791	567	.657	42.3
2400	1.2026	28.814	755	.4464	505	.667	-4.0
2300	1.2122	28.865	732	.4185	454	.675	-47.2
2200	1.2218	28.903	710	.3954	412	.682	-87.8
2100	1.2308	28.929	687	.3768	377	.687	-126.4
2000	1.2391	28.946	664	.3622	348	.691	-163.3
1900	1.2463	28.957	640	.3509	324	.694	-198.9
1800	1.2525	28.964	616	.3424	303	.697	-233.6
1700	1.2578	28.968	592	.3357	284	.699	-267.5
1600	1.2626	28.970	568	.3303	268	.701	-300.8
1500	1.2671	28.971	543	.3256	252	.703	-333.6
1400	1.2716	↓	518	.3212	236	.705	-365.9
1300	1.2764		493	.3168	221	.707	-397.8
1200	1.2817		467	.3121	206	.709	-429.3
1100	1.2877		440	.3070	190	.711	-460.2
1000	1.2945		412	.3015	174	.713	-490.6
900	1.3028		383	.2951	158	.715	-520.5
800	1.3126		352	.2880	142	.717	-549.7
700	1.3236		320	.2806	125	.720	-578.1
600	1.3354		286	.2731	108	.723	-605.8
500	1.3478		250	.2658	91	.726	-632.7
[a]400	1.1941	30.603	215	.2524	75	.723	-676.4
[a]300	1.2422	33.155	180	.2369	60	.707	-730.3

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VI. - THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 40 ATMOSPHERES

(a) Fuel-air ratio, 0.01

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2220	28.859	826×10^{-6}	0.4028	509×10^{-6}	0.654	657.7
2700	1.2285	28.891	805	.3867	468	.665	618.2
2600	1.2350	28.915	784	.3729	433	.674	580.3
2500	1.2413	28.932	762	.3611	404	.682	543.6
2400	1.2475	28.944	741	.3512	379	.687	508.0
2300	1.2535	28.952	719	.3427	357	.691	473.3
2200	1.2592	28.957	698	.3354	337	.694	439.4
2100	1.2648	28.961	676	.3289	319	.697	406.2
2000	1.2703	28.963	654	.3231	303	.698	373.6
1900	1.2757	28.965	632	.3178	287	.700	341.6
1800	1.2811	28.965	610	.3128	272	.701	310.0
1700	1.2866	28.966	588	.3081	258	.701	279.0
1600	1.2920	↓	565	.3035	244	.702	248.4
1500	1.2976	↓	542	.2991	231	.703	218.3
1400	1.3033	↓	519	.2948	217	.704	188.6
1300	1.3091	↓	495	.2905	204	.704	159.3
1200	1.3151	↓	470	.2863	191	.705	130.5
1100	1.3216	↓	445	.2819	178	.706	102.1
1000	1.3285	↓	419	.2775	164	.706	74.1
900	1.3368	↓	391	.2723	150	.707	46.6
800	1.3466	↓	361	.2665	136	.708	19.6
700	1.3576	↓	331	.2605	122	.708	-6.7
600	1.3690	↓	298	.2545	107	.708	-32.5
500	1.3799	↓	263	.2492	92	.709	-57.6
400	1.3892	↓	225	.2449	78	.709	-82.3
[a]300	1.3500	29.523	183	.2397	62	.706	-113.5

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VI. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 40 ATMOSPHERES

(b) Fuel-air ratio, 0.02

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2131	28.827	831×10^{-6}	0.4247	548×10^{-6}	0.644	569.4
2700	1.2204	28.869	809	.4040	497	.657	528.0
2600	1.2276	28.900	788	.3865	456	.668	488.5
2500	1.2346	28.922	766	.3721	421	.677	450.5
2400	1.2414	28.938	745	.3601	392	.684	414.0
2300	1.2477	28.948	723	.3502	367	.689	378.5
2200	1.2537	28.956	701	.3419	346	.693	343.9
2100	1.2594	28.960	679	.3348	327	.695	310.0
2000	1.2649	28.963	657	.3286	310	.697	276.9
1900	1.2702	28.965	635	.3231	293	.699	244.3
1800	1.2754	28.966	612	.3180	278	.700	212.3
1700	1.2806	28.966	589	.3132	263	.701	180.7
1600	1.2859	28.967	566	.3086	249	.702	149.6
1500	1.2913	↓	543	.3041	235	.703	119.0
1400	1.2968		519	.2998	221	.704	88.8
1300	1.3024		495	.2954	208	.705	59.0
1200	1.3084		470	.2910	194	.706	29.7
1100	1.3148		445	.2865	180	.706	.8
1000	1.3217		418	.2818	167	.707	-27.6
900	1.3301		390	.2764	152	.708	-55.5
800	1.3399		360	.2704	137	.709	-82.8
700	1.3509		329	.2641	122	.710	-109.6
600	1.3625		296	.2579	108	.711	-135.7
500	1.3737		261	.2522	93	.712	-161.2
400	1.3836	↓	222	.2474	77	.713	-186.1
[a]300	1.3270	30.118	183	.2392	62	.706	-224.6

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VI. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 40 ATMOSPHERES

(c) Fuel-air ratio, 0.03

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2054	28.796	834×10^{-6}	0.4466	586×10^{-6}	0.636	482.4
2700	1.2132	28.848	813	.4211	526	.651	439.0
2600	1.2211	28.886	791	.3998	477	.664	398.0
2500	1.2288	28.913	770	.3823	437	.674	358.9
2400	1.2360	28.933	748	.3682	404	.681	321.4
2300	1.2427	28.946	726	.3569	377	.687	285.2
2200	1.2489	28.954	704	.3477	354	.691	250.0
2100	1.2547	28.960	682	.3400	334	.694	215.6
2000	1.2600	28.963	659	.3336	316	.696	181.9
1900	1.2652	28.965	637	.3279	299	.698	148.9
1800	1.2702	28.967	614	.3228	283	.700	116.3
1700	1.2752	28.967	591	.3180	268	.701	84.3
1600	1.2802	28.968	567	.3134	253	.702	52.7
1500	1.2854		544	.3090	239	.703	21.6
1400	1.2907		520	.3046	225	.704	-9.1
1300	1.2962		495	.3002	211	.705	-39.3
1200	1.3021		470	.2956	197	.706	-69.1
1100	1.3085		444	.2910	183	.707	-98.4
1000	1.3154		417	.2861	169	.709	-127.3
900	1.3238		389	.2805	154	.710	-155.6
800	1.3336		359	.2742	139	.711	-183.4
700	1.3446		328	.2676	123	.712	-210.4
600	1.3563		295	.2611	108	.713	-236.9
500	1.3678		259	.2551	92	.715	-262.7
400	1.3783		220	.2499	77	.717	-287.9
[a]300	1.3064	30.726	182	.2387	62	.706	-333.5

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VI. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 40 ATMOSPHERES

(d) Fuel-air ratio, 0.04

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1978	28.760	838×10^{-6}	0.4714	627×10^{-6}	0.629	397.5
2700	1.2062	28.824	816	.4403	557	.645	352.0
2600	1.2148	28.871	794	.4142	500	.659	309.3
2500	1.2233	28.904	773	.3931	453	.670	269.0
2400	1.2311	28.927	751	.3764	416	.679	230.5
2300	1.2383	28.943	728	.3634	386	.685	193.6
2200	1.2447	28.953	706	.3531	361	.690	157.7
2100	1.2505	28.960	684	.3449	340	.693	122.9
2000	1.2558	28.964	661	.3382	321	.696	88.7
1900	1.2607	28.966	638	.3324	304	.698	55.2
1800	1.2655	28.967	615	.3273	288	.699	22.2
1700	1.2703	28.968	592	.3226	272	.701	-10.3
1600	1.2750	28.969	568	.3181	257	.702	-42.3
1500	1.2799	↓	544	.3137	243	.703	-73.9
1400	1.2850		520	.3093	228	.704	-105.0
1300	1.2904		495	.3048	214	.705	-135.8
1200	1.2962		470	.3002	199	.707	-166.0
1100	1.3025		444	.2954	185	.708	-195.8
1000	1.3095		416	.2903	170	.710	-225.1
900	1.3179		388	.2844	155	.711	-253.8
800	1.3277		358	.2779	140	.713	-281.9
700	1.3387		326	.2711	124	.714	-309.4
600	1.3504		293	.2644	108	.716	-336.2
500	1.3622		257	.2580	92	.718	-362.3
[a]400	1.2141	29.537	219	.2500	76	.718	-394.1
[a]300	1.2880	31.346	182	.2382	61	.706	-440.3

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VI. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 40 ATMOSPHERES

(e) Fuel-air ratio, 0.05

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1897	28.710	840×10^{-6}	0.5029	679×10^{-6}	0.623	316.0
2700	1.1984	28.790	819	.4651	596	.639	267.6
2600	1.2078	28.849	797	.4328	528	.653	222.8
2500	1.2172	28.891	775	.4065	473	.666	180.9
2400	1.2260	28.920	753	.3860	430	.675	141.3
2300	1.2339	28.940	730	.3703	396	.683	103.5
2200	1.2408	28.952	708	.3585	369	.688	67.1
2100	1.2467	28.959	685	.3495	346	.692	31.7
2000	1.2520	28.964	662	.3424	326	.695	-2.9
1900	1.2568	28.967	639	.3365	309	.697	-36.8
1800	1.2613	28.968	616	.3315	292	.699	-70.2
1700	1.2658	28.969	592	.3269	276	.700	-103.1
1600	1.2703	28.969	568	.3225	261	.702	-135.6
1500	1.2749	28.970	544	.3182	246	.703	-167.6
1400	1.2798	↓	519	.3138	231	.705	-199.2
1300	1.2850	↓	494	.3093	217	.706	-230.4
1200	1.2906	↓	469	.3046	202	.707	-261.1
1100	1.2969	↓	442	.2996	187	.709	-291.3
1000	1.3038	↓	415	.2943	172	.711	-321.0
900	1.3122	↓	386	.2883	156	.712	-350.1
800	1.3221	↓	356	.2816	140	.714	-378.6
700	1.3331	↓	324	.2745	124	.716	-406.4
600	1.3449	↓	291	.2675	108	.718	-433.5
500	1.3568	↓	255	.2608	92	.721	-459.9
[a]400	1.2083	30.134	219	.2499	76	.718	-498.4
[a]300	1.2712	31.979	181	.2377	61	.706	-545.1

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VI. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 40 ATMOSPHERES

(f) Fuel-air ratio, 0.06

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1803	28.623	842×10^{-6}	0.5470	746×10^{-6}	0.617	241.5
2700	1.1884	28.727	821	.5036	653	.633	188.9
2600	1.1980	28.807	799	.4640	573	.647	140.6
2500	1.2083	28.865	777	.4297	506	.659	96.0
2400	1.2187	28.905	754	.4021	453	.670	54.4
2300	1.2282	28.932	732	.3810	411	.679	15.3
2200	1.2364	28.948	709	.3655	378	.686	-22.0
2100	1.2431	28.958	686	.3544	352	.691	-57.9
2000	1.2487	28.964	663	.3463	331	.694	-92.9
1900	1.2535	28.967	640	.3402	312	.697	-127.2
1800	1.2578	28.969	616	.3352	296	.699	-161.0
1700	1.2619	28.970	592	.3307	280	.700	-194.3
1600	1.2660	28.970	568	.3265	264	.702	-227.2
1500	1.2703	28.971	544	.3224	249	.703	-259.6
1400	1.2749	↓	519	.3181	234	.705	-291.6
1300	1.2799	↓	494	.3136	219	.706	-323.2
1200	1.2855	↓	468	.3089	204	.708	-354.3
1100	1.2916	↓	441	.3038	189	.710	-385.0
1000	1.2985	↓	414	.2984	173	.712	-415.1
900	1.3069	↓	385	.2921	157	.714	-444.6
800	1.3167	↓	354	.2852	141	.716	-473.5
700	1.3277	↓	322	.2779	125	.718	-501.6
600	1.3396	↓	288	.2706	108	.721	-529.1
500	1.3518	↓	252	.2636	92	.724	-555.8
[a]400	1.2026	30.743	218	.2499	76	.719	-600.7
[a]300	1.2561	32.626	180	.2372	61	.706	-647.9

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VI. - Concluded. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF ASTM-A-1 AND AIR AT 40 ATMOSPHERES

(g) Fuel-air ratio, 0.06817 (stoichiometric)

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1748	28.460	843×10^{-6}	0.5802	787×10^{-6}	0.621	195.7
2700	1.1809	28.583	821	.5401	697	.636	139.7
2600	1.1881	28.684	799	.5024	618	.650	87.6
2500	1.1964	28.765	777	.4682	551	.661	39.1
2400	1.2054	28.827	755	.4380	494	.670	-6.2
2300	1.2147	28.875	732	.4122	446	.677	-48.7
2200	1.2238	28.909	710	.3909	406	.683	-88.8
2100	1.2324	28.933	687	.3737	373	.688	-127.0
2000	1.2402	28.948	664	.3602	346	.691	-163.7
1900	1.2471	28.959	640	.3497	322	.694	-199.1
1800	1.2530	28.965	616	.3416	302	.697	-233.7
1700	1.2581	28.968	592	.3353	284	.699	-267.5
1600	1.2627	28.970	568	.3301	267	.701	-300.8
1500	1.2671	28.971	543	.3255	252	.703	-333.6
1400	1.2716	↓	518	.3212	236	.705	-365.9
1300	1.2764		493	.3168	221	.707	-397.8
1200	1.2817		467	.3121	205	.709	-429.3
1100	1.2877		440	.3070	190	.711	-460.2
1000	1.2945		412	.3015	174	.713	-490.6
900	1.3028		383	.2951	158	.715	-520.5
800	1.3126		352	.2880	142	.717	-549.6
700	1.3236		320	.2806	125	.720	-578.1
600	1.3354		286	.2731	108	.723	-605.8
500	1.3478	↓	250	.2658	91	.726	-632.7
[a]400	1.1980	31.250	217	.2498	75	.720	-682.9
[a]300	1.2446	33.164	180	.2368	60	.707	-730.4

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VII. - THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 20 ATMOSPHERES

(a) Fuel-air ratio, 0.01

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2129	28.600	827×10^{-6}	0.4317	571×10^{-6}	0.626	655.0
2700	1.2204	28.646	806	.4095	513	.643	612.9
2600	1.2280	28.680	784	.3909	466	.657	572.9
2500	1.2354	28.704	763	.3751	428	.669	534.7
2400	1.2427	28.722	741	.3621	396	.678	497.8
2300	1.2496	28.734	720	.3513	369	.685	462.2
2200	1.2561	28.742	698	.3422	346	.690	427.5
2100	1.2624	28.747	676	.3345	326	.693	393.7
2000	1.2684	28.751	654	.3278	308	.695	360.6
1900	1.2742	28.753	632	.3218	292	.697	328.1
1800	1.2799	28.754	610	.3164	276	.699	296.2
1700	1.2855	28.754	587	.3113	261	.700	264.8
1600	1.2911	28.755	565	.3066	247	.701	233.9
1500	1.2968	↓	542	.3020	233	.702	203.5
1400	1.3025	↓	518	.2975	219	.702	173.5
1300	1.3084	↓	494	.2932	206	.703	144.0
1200	1.3145	↓	469	.2888	193	.704	114.9
1100	1.3210	↓	444	.2844	179	.705	86.2
1000	1.3280	↓	418	.2798	166	.706	58.0
900	1.3364	↓	390	.2745	151	.707	30.3
800	1.3463	↓	360	.2687	137	.708	3.1
700	1.3573	↓	329	.2625	122	.709	-23.4
600	1.3687	↓	297	.2566	107	.709	-49.4
500	1.3796	↓	262	.2512	93	.710	-74.8
400	1.3888	↓	223	.2469	78	.711	-99.6
[a]300	1.3198	29.698	183	.2401	62	.706	-135.8

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 20 ATMOSPHERES

(b) Fuel-air ratio, 0.02

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2028	28.353	832×10^{-6}	0.4646	637×10^{-6}	0.607	558.5
2700	1.2109	28.412	811	.4361	563	.628	513.5
2600	1.2192	28.455	789	.4122	504	.646	471.1
2500	1.2274	28.487	767	.3925	456	.660	430.9
2400	1.2353	28.509	746	.3764	418	.671	392.5
2300	1.2427	28.525	724	.3634	387	.679	355.6
2200	1.2496	28.535	702	.3528	361	.685	319.8
2100	1.2560	28.542	679	.3441	339	.690	284.9
2000	1.2621	28.546	657	.3367	320	.693	250.9
1900	1.2679	28.549	635	.3303	302	.695	217.6
1800	1.2734	28.551	612	.3246	285	.696	184.8
1700	1.2789	28.552	589	.3194	270	.698	152.6
1600	1.2843	↓	566	.3145	255	.699	120.9
1500	1.2898	↓	542	.3098	240	.700	89.7
1400	1.2954	↓	518	.3052	226	.702	59.0
1300	1.3012	↓	494	.3006	211	.703	28.7
1200	1.3073	↓	469	.2960	197	.704	-1.1
1100	1.3139	↓	443	.2913	183	.705	-30.5
1000	1.3210	↓	416	.2864	169	.706	-59.4
900	1.3295	↓	388	.2808	154	.708	-87.8
800	1.3394	↓	358	.2746	139	.709	-115.5
700	1.3504	↓	327	.2682	123	.711	-142.7
600	1.3620	↓	294	.2619	108	.712	-169.2
500	1.3731	↓	258	.2561	93	.714	-195.1
400	1.3828	↓	220	.2514	77	.717	-220.4
[a]300	1.2897	30.509	183	.2399	62	.706	-269.0

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 20 ATMOSPHERES

(c) Fuel-air ratio, 0.03

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1942	28.115	837×10^{-6}	0.4978	703×10^{-6}	0.593	463.4
2700	1.2028	28.187	815	.4626	613	.616	415.4
2600	1.2117	28.240	793	.4330	541	.636	370.7
2500	1.2206	28.279	771	.4089	484	.652	328.7
2400	1.2291	28.306	749	.3896	439	.665	288.8
2300	1.2370	28.324	727	.3744	403	.675	250.6
2200	1.2442	28.336	705	.3624	375	.682	213.8
2100	1.2507	28.344	682	.3527	350	.687	178.1
2000	1.2568	28.350	659	.3448	329	.690	143.2
1900	1.2624	28.353	637	.3382	311	.693	109.0
1800	1.2678	28.354	613	.3323	293	.695	75.5
1700	1.2730	28.355	590	.3270	277	.697	42.6
1600	1.2782	28.356	566	.3221	261	.698	10.1
1500	1.2835	↓	543	.3173	246	.699	-21.9
1400	1.2890	↓	518	.3126	231	.701	-53.3
1300	1.2947	↓	493	.3079	216	.702	-84.4
1200	1.3007	↓	468	.3031	202	.704	-114.9
1100	1.3073	↓	442	.2981	187	.705	-145.0
1000	1.3145	↓	415	.2929	172	.707	-174.5
900	1.3231	↓	386	.2870	156	.709	-203.5
800	1.3330	↓	356	.2805	140	.711	-231.9
700	1.3441	↓	324	.2737	124	.713	-259.6
600	1.3557	↓	291	.2671	109	.716	-286.7
500	1.3671	↓	255	.2610	93	.718	-313.1
400	1.3773	↓	216	.2558	76	.722	-338.9
[a]300	1.2639	31.349	182	.2397	62	.706	-399.6

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 20 ATMOSPHERES

(d) Fuel-air ratio, 0.04

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1860	27.875	840×10^{-6}	0.5360	777×10^{-6}	0.580	371.2
2700	1.1948	27.963	819	.4930	669	.604	319.8
2600	1.2044	28.028	797	.4565	582	.625	272.4
2500	1.2141	28.075	775	.4268	513	.644	228.3
2400	1.2234	28.108	752	.4033	461	.659	186.8
2300	1.2319	28.130	730	.3853	420	.670.	147.4
2200	1.2395	28.144	707	.3715	387	.678	109.6
2100	1.2462	28.154	684	.3608	361	.684	73.0
2000	1.2522	28.159	661	.3524	338	.688	37.4
1900	1.2577	28.163	638	.3455	319	.691	2.5
1800	1.2628	28.165	614	.3396	301	.694	-31.7
1700	1.2678	28.166	591	.3343	284	.696	-65.4
1600	1.2728	28.166	567	.3293	268	.697	-98.6
1500	1.2778	28.167	542	.3246	252	.699	-131.3
1400	1.2830	↓	518	.3198	236	.700	-163.5
1300	1.2886		492	.3150	221	.702	-195.3
1200	1.2946		467	.3100	205	.704	-226.5
1100	1.3012		440	.3048	190	.706	-257.3
1000	1.3085		413	.2993	174	.708	-287.5
900	1.3171		384	.2931	158	.710	-317.1
800	1.3271		353	.2862	142	.713	-346.1
700	1.3382		321	.2792	125	.716	-374.3
600	1.3499		287	.2722	109	.719	-401.9
500	1.3614	↓	251	.2657	92	.723	-428.9
[a]400	1.1922	28.496	213	.2587	76	.726	-459.0
[a]300	1.2416	32.218	181	.2394	61	.706	-527.8

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 20 ATMOSPHERES

(e) Fuel-air ratio, 0.05

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1771	27.614	843×10^{-6}	0.5860	869×10^{-6}	0.568	284.9
2700	1.1855	27.724	821	.5352	743	.591	228.9
2600	1.1954	27.808	799	.4900	639	.613	177.7
2500	1.2060	27.869	777	.4519	555	.633	130.7
2400	1.2166	27.911	755	.4215	489	.650	87.1
2300	1.2264	27.939	732	.3983	439	.664	46.1
2200	1.2349	27.957	709	.3812	401	.674	7.2
2100	1.2422	27.968	686	.3687	371	.681	-30.3
2000	1.2484	27.975	662	.3594	347	.686	-66.6
1900	1.2538	27.979	639	.3522	326	.690	-102.2
1800	1.2587	27.981	615	.3462	307	.693	-137.1
1700	1.2633	27.982	591	.3410	290	.695	-171.5
1600	1.2679	27.983	566	.3362	273	.697	-205.3
1500	1.2727	↓	542	.3315	257	.698	-238.7
1400	1.2777	↓	517	.3268	241	.700	-271.6
1300	1.2831	↓	491	.3219	225	.702	-304.1
1200	1.2890	↓	465	.3167	209	.704	-336.0
1100	1.2955	↓	438	.3113	193	.707	-367.4
1000	1.3028	↓	410	.3055	177	.709	-398.2
900	1.3115	↓	381	.2990	160	.712	-428.5
800	1.3215	↓	350	.2919	143	.715	-458.0
700	1.3326	↓	318	.2845	126	.718	-486.8
600	1.3444	↓	284	.2772	109	.722	-514.9
500	1.3561	↓	248	.2704	92	.727	-542.3
[a]400	1.1860	29.293	212	.2588	75	.727	-584.2
[a]300	1.2221	33.119	180	.2392	61	.706	-653.5

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 20 ATMOSPHERES

(f) Fuel-air ratio, 0.06

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1695	27.260	844×10^{-6}	0.6406	946×10^{-6}	0.572	216.7
2700	1.1757	27.397	823	.5917	820	.594	155.1
2600	1.1831	27.508	801	.5463	714	.613	98.2
2500	1.1918	27.597	778	.5050	625	.629	45.7
2400	1.2014	27.666	756	.4685	551	.642	-2.9
2300	1.2117	27.717	733	.4371	491	.653	-48.2
2200	1.2222	27.752	710	.4107	440	.662	-90.5
2100	1.2324	27.776	687	.3893	399	.670	-130.5
2000	1.2416	27.791	663	.3728	365	.678	-168.5
1900	1.2491	27.799	639	.3609	337	.684	-205.2
1800	1.2551	27.802	615	.3528	315	.689	-240.9
1700	1.2599	27.804	591	.3469	296	.693	-275.8
1600	1.2643	27.805	566	.3421	278	.696	-310.3
1500	1.2686	↓	541	.3376	262	.698	-344.2
1400	1.2732	↓	515	.3331	245	.700	-377.8
1300	1.2783	↓	489	.3283	229	.702	-410.9
1200	1.2839	↓	463	.3232	212	.705	-443.4
1100	1.2903	↓	436	.3176	196	.707	-475.5
1000	1.2977	↓	408	.3116	179	.710	-506.9
900	1.3063	↓	378	.3048	162	.713	-537.8
800	1.3163	↓	347	.2974	144	.716	-567.9
700	1.3274	↓	315	.2897	127	.720	-597.2
600	1.3392	↓	280	.2821	109	.725	-625.8
500	1.3511	↓	244	.2750	92	.731	-653.7
[a]400	1.1798	30.120	211	.2589	75	.728	-707.1
[a]300	1.2050	34.053	180	.2389	61	.706	-776.8

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VII. - Concluded. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 20 ATMOSPHERES

(g) Fuel-air ratio, 0.06074 (stoichiometric)

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1694	27.225	844×10^{-6}	0.6420	946×10^{-6}	0.573	213.3
2700	1.1755	27.362	823	.5932	819	.596	151.5
2600	1.1829	27.474	801	.5480	713	.616	94.5
2500	1.1914	27.564	778	.5070	624	.633	41.8
2400	1.2008	27.633	756	.4711	551	.647	-7.1
2300	1.2106	27.685	733	.4404	491	.658	-52.6
2200	1.2205	27.723	710	.4151	442	.668	-95.3
2100	1.2298	27.749	687	.3948	402	.675	-135.8
2000	1.2384	27.767	663	.3788	369	.681	-174.4
1900	1.2459	27.778	639	.3665	342	.685	-211.7
1800	1.2524	27.785	615	.3570	319	.689	-247.8
1700	1.2581	27.789	590	.3497	298	.692	-283.1
1600	1.2632	27.791	566	.3437	280	.695	-317.8
1500	1.2680	27.792	541	.3385	262	.697	-351.9
1400	1.2728	↓	515	.3336	246	.700	-385.5
1300	1.2780	↓	489	.3287	229	.702	-418.6
1200	1.2837	↓	463	.3236	212	.705	-451.3
1100	1.2900	27.793	435	.3180	196	.707	-483.3
1000	1.2973	↓	407	.3120	179	.710	-514.9
900	1.3059	↓	378	.3052	162	.713	-545.7
800	1.3160	↓	347	.2978	144	.716	-575.9
700	1.3271	↓	314	.2901	127	.720	-605.3
600	1.3389	↓	280	.2825	109	.725	-633.9
500	1.3508	↓	243	.2753	92	.731	-661.8
[a]400	1.1794	30.182	211	.2589	75	.728	-716.1
[a]300	1.2038	34.124	180	.2389	61	.706	-785.7

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VIII. - THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 30 ATMOSPHERES

(a) Fuel-air ratio, 0.01

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2170	28.624	827×10^{-6}	0.4190	544×10^{-6}	0.637	651.3
2700	1.2239	28.662	806	.4000	495	.652	610.4
2600	1.2309	28.691	784	.3838	454	.664	571.2
2500	1.2378	28.712	763	.3702	419	.674	533.5
2400	1.2445	28.726	741	.3587	390	.681	497.1
2300	1.2509	28.737	720	.3490	366	.687	461.7
2200	1.2571	28.744	698	.3407	344	.691	427.2
2100	1.2630	28.748	676	.3336	325	.694	393.5
2000	1.2688	28.751	654	.3272	308	.696	360.5
1900	1.2744	28.753	632	.3215	291	.697	328.1
1800	1.2800	28.754	610	.3162	276	.699	296.2
1700	1.2856	28.755	587	.3112	261	.700	264.8
1600	1.2911	↓	565	.3065	247	.701	233.9
1500	1.2968	↓	542	.3020	233	.702	203.5
1400	1.3025	↓	518	.2975	219	.702	173.5
1300	1.3084	↓	494	.2932	206	.703	144.0
1200	1.3145	↓	469	.2888	193	.704	114.9
1100	1.3210	↓	444	.2844	179	.705	86.2
1000	1.3280	↓	418	.2798	166	.706	58.0
900	1.3364	↓	390	.2745	151	.707	30.3
800	1.3463	↓	360	.2687	137	.708	3.1
700	1.3573	↓	329	.2625	122	.709	-23.4
600	1.3687	↓	297	.2566	107	.709	-49.4
500	1.3796	↓	262	.2512	93	.710	-74.8
400	1.3888	↓	223	.2469	78	.711	-99.6
[a]300	1.3299	29.715	183	.2400	62	.706	-136.0

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VIII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 30 ATMOSPHERES

(b) Fuel-air ratio, 0.02

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2074	28.383	832×10^{-6}	0.4480	601×10^{-6}	0.621	553.7
2700	1.2150	28.433	811	.4236	538	.638	510.1
2600	1.2227	28.470	789	.4031	487	.654	468.8
2500	1.2302	28.496	767	.3860	445	.666	429.4
2400	1.2375	28.515	746	.3720	411	.675	391.5
2300	1.2443	28.529	724	.3604	383	.682	354.9
2200	1.2507	28.538	702	.3509	358	.687	319.4
2100	1.2568	28.544	679	.3429	337	.690	284.7
2000	1.2626	28.547	657	.3359	319	.693	250.8
1900	1.2682	28.550	635	.3299	301	.695	217.5
1800	1.2736	28.551	612	.3243	285	.697	184.8
1700	1.2790	28.552	589	.3192	269	.698	152.6
1600	1.2844	↓	566	.3144	254	.699	120.9
1500	1.2898	↓	542	.3097	240	.700	89.7
1400	1.2954	↓	518	.3052	226	.702	59.0
1300	1.3012	↓	494	.3006	211	.703	28.7
1200	1.3073	↓	469	.2960	197	.704	-1.1
1100	1.3139	↓	443	.2913	183	.705	-30.5
1000	1.3210	↓	416	.2864	169	.706	-59.4
900	1.3295	↓	388	.2808	154	.708	-87.8
800	1.3394	↓	358	.2746	139	.709	-115.5
700	1.3504	↓	327	.2682	123	.711	-142.7
600	1.3620	↓	294	.2619	108	.712	-169.2
500	1.3731	↓	258	.2561	93	.714	-195.1
400	1.3828	↓	220	.2514	77	.717	-220.4
[a]300	1.2975	30.527	183	.2398	62	.706	-269.2

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VIII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 30 ATMOSPHERES

(c) Fuel-air ratio, 0.03

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1993	28.152	837×10^{-6}	0.4770	657×10^{-6}	0.607	457.4
2700	1.2074	28.212	815	.4468	581	.627	411.2
2600	1.2157	28.257	793	.4214	519	.645	367.9
2500	1.2239	28.290	771	.4007	469	.659	326.8
2400	1.2317	28.313	749	.3841	430	.670	287.6
2300	1.2389	28.329	727	.3708	398	.678	249.9
2200	1.2455	28.339	705	.3600	371	.684	213.3
2100	1.2517	28.346	682	.3513	348	.688	177.8
2000	1.2574	28.350	659	.3440	328	.691	143.0
1900	1.2628	28.353	637	.3377	310	.693	109.0
1800	1.2680	28.355	613	.3320	293	.695	75.5
1700	1.2732	28.356	590	.3269	277	.697	42.5
1600	1.2783	↓	566	.3220	261	.698	10.1
1500	1.2835	↓	542	.3173	246	.700	-21.9
1400	1.2890	↓	518	.3126	231	.701	-53.3
1300	1.2947	↓	493	.3079	216	.702	-84.4
1200	1.3007	↓	468	.3031	202	.704	-114.9
1100	1.3073	↓	442	.2981	187	.705	-145.0
1000	1.3145	↓	415	.2929	172	.707	-174.5
900	1.3231	↓	386	.2870	156	.709	-203.5
800	1.3330	↓	356	.2805	140	.711	-231.9
700	1.3441	↓	324	.2737	124	.713	-259.6
600	1.3557	↓	291	.2671	109	.716	-286.7
500	1.3671	↓	255	.2610	93	.718	-313.1
[a]400	1.2039	28.953	218	.2532	77	.719	-345.8
[a]300	1.2700	31.367	182	.2396	62	.706	-399.8

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VIII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 30 ATMOSPHERES

(d) Fuel-air ratio, 0.04

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1913	27.920	841×10^{-6}	0.5105	721×10^{-6}	0.595	363.7
2700	1.1999	27.994	819	.4733	629	.616	314.6
2600	1.2089	28.049	797	.4419	554	.636	268.8
2500	1.2179	28.089	775	.4165	495	.651	226.0
2400	1.2264	28.116	752	.3964	449	.664	185.4
2300	1.2341	28.135	730	.3808	413	.674	146.5
2200	1.2410	28.147	707	.3686	383	.681	109.1
2100	1.2473	28.155	684	.3591	358	.686	72.7
2000	1.2529	28.160	661	.3514	337	.689	37.2
1900	1.2581	28.163	638	.3449	318	.692	2.4
1800	1.2631	28.165	614	.3393	300	.694	-31.8
1700	1.2679	28.166	591	.3341	284	.696	-65.5
1600	1.2728	28.166	567	.3293	268	.697	-98.6
1500	1.2778	28.167	542	.3245	252	.699	-131.3
1400	1.2831	↓	518	.3198	236	.700	-163.5
1300	1.2886		492	.3150	221	.702	-195.3
1200	1.2946		467	.3100	205	.704	-226.5
1100	1.3012		440	.3048	190	.706	-257.3
1000	1.3085		413	.2993	174	.708	-287.5
900	1.3171		384	.2931	158	.710	-317.1
800	1.3271		353	.2862	142	.713	-346.1
700	1.3382		321	.2792	125	.716	-374.3
600	1.3499		287	.2722	109	.719	-401.9
500	1.3614		251	.2657	92	.723	-428.8
[a]400	1.1961	29.756	217	.2533	76	.720	-473.1
[a]300	1.2464	32.237	181	.2394	61	.706	-528.0

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VIII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 30 ATMOSPHERES

(e) Fuel-air ratio, 0.05

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1824	27.669	843×10^{-6}	0.5557	804×10^{-6}	0.583	275.4
2700	1.1909	27.764	822	.5106	694	.604	222.1
2600	1.2005	27.835	800	.4711	604	.624	173.1
2500	1.2106	27.887	777	.4382	531	.641	127.7
2400	1.2203	27.922	755	.4121	474	.656	85.2
2300	1.2291	27.946	732	.3923	430	.668	45.0
2200	1.2368	27.961	709	.3775	396	.677	6.6
2100	1.2434	27.970	686	.3665	368	.683	-30.6
2000	1.2491	27.976	662	.3582	345	.687	-66.8
1900	1.2542	27.979	639	.3515	325	.690	-102.3
1800	1.2589	27.981	615	.3459	307	.693	-137.2
1700	1.2634	27.982	591	.3409	290	.695	-171.5
1600	1.2680	27.983	566	.3361	273	.697	-205.3
1500	1.2727	↓	542	.3315	257	.698	-238.7
1400	1.2777	↓	517	.3267	241	.700	-271.6
1300	1.2831	↓	491	.3219	225	.702	-304.1
1200	1.2890	↓	465	.3167	209	.704	-336.0
1100	1.2955	↓	438	.3113	193	.707	-367.4
1000	1.3028	↓	410	.3055	177	.709	-398.2
900	1.3115	↓	381	.2990	160	.712	-428.5
800	1.3215	↓	350	.2919	143	.715	-458.0
700	1.3326	↓	318	.2845	126	.718	-486.8
600	1.3444	↓	284	.2772	109	.722	-514.9
500	1.3561	↓	248	.2704	92	.727	-542.3
[a]400	1.1884	30.588	216	.2534	76	.721	-598.0
[a]300	1.2259	33.138	181	.2391	61	.706	-653.6

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VIII. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 30 ATMOSPHERES

(f) Fuel-air ratio, 0.06

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1739	27.327	845×10^{-6}	0.6098	879×10^{-6}	0.586	204.7
2700	1.1802	27.448	823	.5659	769	.605	146.0
2600	1.1877	27.546	801	.5251	676	.622	91.5
2500	1.1962	27.625	779	.4881	597	.636	40.8
2400	1.2056	27.685	756	.4554	532	.648	-6.3
2300	1.2154	27.729	733	.4273	477	.657	-50.4
2200	1.2253	27.760	710	.4036	431	.665	-91.9
2100	1.2348	27.781	687	.3845	392	.673	-131.3
2000	1.2432	27.793	663	.3698	361	.680	-169.0
1900	1.2501	27.800	639	.3594	335	.686	-205.4
1800	1.2556	27.803	615	.3520	314	.690	-240.9
1700	1.2602	27.804	591	.3466	295	.693	-275.9
1600	1.2644	27.805	566	.3419	278	.696	-310.3
1500	1.2686	↓	541	.3376	262	.698	-344.2
1400	1.2732	↓	515	.3331	245	.700	-377.8
1300	1.2783	↓	489	.3283	229	.702	-410.9
1200	1.2839	↓	463	.3232	212	.705	-443.4
1100	1.2903	↓	436	.3176	196	.707	-475.5
1000	1.2977	↓	408	.3116	179	.710	-506.9
900	1.3063	↓	378	.3048	162	.713	-537.8
800	1.3163	↓	347	.2974	144	.716	-567.9
700	1.3274	↓	315	.2897	127	.720	-597.2
600	1.3392	↓	280	.2821	109	.725	-625.8
500	1.3511	↓	244	.2750	92	.731	-653.7
[a]400	1.1809	31.451	215	.2536	75	.722	-720.5
[a]300	1.2080	34.073	180	.2389	61	.706	-776.9

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE VIII. - Concluded. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 30 ATMOSPHERES

(g) Fuel-air ratio, 0.06074 (stoichiometric)

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1738	27.292	845×10^{-6}	0.6112	879×10^{-6}	0.588	201.3
2700	1.1800	27.413	823	.5674	769	.608	142.4
2600	1.1874	27.512	801	.5269	675	.625	87.7
2500	1.1958	27.591	779	.4902	596	.640	36.9
2400	1.2048	27.652	756	.4582	531	.652	-10.5
2300	1.2142	27.698	733	.4309	477	.662	-54.9
2200	1.2234	27.731	710	.4083	433	.670	-96.8
2100	1.2321	27.755	687	.3901	396	.677	-136.7
2000	1.2401	27.770	663	.3757	365	.682	-175.0
1900	1.2471	27.780	639	.3646	340	.686	-212.0
1800	1.2532	27.786	615	.3559	317	.690	-248.0
1700	1.2585	27.789	590	.3491	298	.692	-283.2
1600	1.2634	27.791	566	.3434	280	.695	-317.8
1500	1.2681	27.792	541	.3384	262	.697	-351.9
1400	1.2729	↓	515	.3336	246	.700	-385.5
1300	1.2780	↓	489	.3287	229	.702	-418.6
1200	1.2837	↓	463	.3236	212	.705	-451.3
1100	1.2900	27.793	435	.3180	196	.707	-483.3
1000	1.2973	↓	407	.3120	179	.710	-514.9
900	1.3059	↓	378	.3052	162	.713	-545.7
800	1.3160	↓	347	.2978	144	.716	-575.9
700	1.3271	↓	314	.2901	127	.720	-605.3
600	1.3389	↓	280	.2825	109	.725	-633.9
500	1.3508	↓	243	.2753	92	.731	-661.8
[a]400	1.1804	31.515	215	.2536	75	.722	-729.4
[a]300	1.2067	34.143	180	.2389	61	.706	-785.9

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IX. - THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 40 ATMOSPHERES

(a) Fuel-air ratio, 0.01

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2196	28.639	827×10^{-6}	0.4113	529×10^{-6}	0.644	649.0
2700	1.2262	28.672	806	.3942	484	.657	608.8
2600	1.2328	28.698	784	.3796	446	.668	570.1
2500	1.2393	28.716	763	.3672	414	.676	532.8
2400	1.2456	28.730	741	.3566	387	.683	496.6
2300	1.2517	28.739	720	.3476	364	.688	461.4
2200	1.2577	28.745	698	.3398	343	.692	427.0
2100	1.2634	28.749	676	.3330	324	.694	393.4
2000	1.2690	28.752	654	.3268	307	.696	360.4
1900	1.2746	28.753	632	.3213	291	.698	328.0
1800	1.2801	28.754	610	.3161	276	.699	296.2
1700	1.2856	28.755	587	.3112	261	.700	264.8
1600	1.2912	↓	565	.3065	247	.701	233.9
1500	1.2968	↓	542	.3020	233	.702	203.5
1400	1.3025	↓	518	.2975	219	.702	173.5
1300	1.3084	↓	494	.2932	206	.703	144.0
1200	1.3145	↓	469	.2888	193	.704	114.9
1100	1.3210	↓	444	.2844	179	.705	86.2
1000	1.3280	↓	418	.2798	166	.706	58.0
900	1.3364	↓	390	.2745	151	.707	30.3
800	1.3463	↓	360	.2687	137	.708	3.1
700	1.3573	↓	329	.2625	122	.709	-23.4
600	1.3687	↓	297	.2566	107	.709	-49.4
500	1.3796	↓	262	.2512	93	.710	-74.8
400	1.3888	↓	223	.2469	78	.711	-99.6
[a]300	1.3353	29.724	183	.2400	62	.706	-136.1

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IX. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 40 ATMOSPHERES

(b) Fuel-air ratio, 0.02

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2104	28.402	833×10^{-6}	0.4378	580×10^{-6}	0.629	550.7
2700	1.2177	28.446	811	.4159	523	.645	508.1
2600	1.2249	28.478	789	.3974	477	.658	467.4
2500	1.2320	28.502	768	.3820	438	.669	428.5
2400	1.2388	28.519	746	.3692	407	.677	390.9
2300	1.2453	28.531	724	.3586	380	.683	354.6
2200	1.2515	28.539	702	.3497	357	.688	319.2
2100	1.2573	28.544	679	.3421	336	.691	284.6
2000	1.2629	28.548	657	.3355	318	.693	250.7
1900	1.2684	28.550	635	.3296	301	.695	217.4
1800	1.2737	28.551	612	.3242	285	.697	184.8
1700	1.2791	28.552	589	.3191	269	.698	152.6
1600	1.2844	↓	566	.3144	254	.699	120.9
1500	1.2899		542	.3097	240	.700	89.7
1400	1.2954		518	.3052	226	.702	59.0
1300	1.3012		494	.3006	211	.703	28.7
1200	1.3073		469	.2960	197	.704	-1.1
1100	1.3139		443	.2913	183	.705	-30.5
1000	1.3210		416	.2864	169	.706	-59.4
900	1.3295		388	.2808	154	.708	-87.8
800	1.3394		358	.2746	139	.709	-115.5
700	1.3504		327	.2682	123	.711	-142.7
600	1.3620		294	.2619	108	.712	-169.2
500	1.3731	↓	258	.2561	93	.714	-195.1
[a]400	1.2190	28.774	220	.2504	77	.716	-223.0
[a]300	1.3017	30.536	183	.2398	62	.706	-269.3

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IX. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 40 ATMOSPHERES

(c) Fuel-air ratio, 0.03

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.2026	28.174	837×10^{-6}	0.4642	630×10^{-6}	0.617	453.7
2700	1.2104	28.228	815	.4371	561	.635	408.7
2600	1.2183	28.268	793	.4144	506	.650	366.1
2500	1.2260	28.297	771	.3958	461	.663	325.6
2400	1.2333	28.317	749	.3807	424	.672	286.8
2300	1.2401	28.331	727	.3685	394	.680	249.4
2200	1.2464	28.341	705	.3586	369	.685	213.1
2100	1.2522	28.347	682	.3504	347	.689	177.6
2000	1.2577	28.351	659	.3434	328	.691	143.0
1900	1.2630	28.353	637	.3373	310	.694	108.9
1800	1.2681	28.355	613	.3318	293	.695	75.5
1700	1.2732	28.356	590	.3268	277	.697	42.5
1600	1.2783	↓	566	.3219	261	.698	10.1
1500	1.2836	↓	542	.3172	246	.700	-21.9
1400	1.2890	↓	518	.3126	231	.701	-53.3
1300	1.2947	↓	493	.3079	216	.702	-84.4
1200	1.3007	↓	468	.3031	202	.704	-114.9
1100	1.3073	↓	442	.2981	187	.705	-145.0
1000	1.3145	↓	415	.2929	172	.707	-174.5
900	1.3231	↓	386	.2870	156	.709	-203.5
800	1.3330	↓	356	.2805	140	.711	-231.9
700	1.3441	↓	324	.2737	124	.713	-259.6
600	1.3557	↓	291	.2671	109	.716	-286.7
500	1.3671	↓	255	.2610	93	.718	-313.1
[a]400	1.2095	29.565	219	.2505	77	.716	-352.6
[a]300	1.2732	31.376	182	.2395	62	.706	-399.9

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IX. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 40 ATMOSPHERES

(d) Fuel-air ratio, 0.04

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1949	27.947	841×10^{-6}	0.4947	688×10^{-6}	0.605	359.1
2700	1.2033	28.013	819	.4612	605	.625	311.3
2600	1.2119	28.062	797	.4330	538	.642	266.7
2500	1.2203	28.097	775	.4103	484	.656	224.6
2400	1.2282	28.122	752	.3922	442	.667	184.5
2300	1.2355	28.138	730	.3780	408	.676	146.0
2200	1.2420	28.149	707	.3669	380	.682	108.8
2100	1.2479	28.156	684	.3580	357	.686	72.5
2000	1.2533	28.161	661	.3507	336	.690	37.1
1900	1.2584	28.164	638	.3445	318	.692	2.4
1800	1.2632	28.165	614	.3391	300	.694	-31.8
1700	1.2680	28.166	591	.3340	284	.696	-65.5
1600	1.2729	28.166	567	.3292	268	.697	-98.6
1500	1.2779	28.167	542	.3245	252	.699	-131.3
1400	1.2831	↓	518	.3198	236	.700	-163.5
1300	1.2886		492	.3150	221	.702	-195.3
1200	1.2946		467	.3100	205	.704	-226.5
1100	1.3012		440	.3048	190	.706	-257.3
1000	1.3085		413	.2993	174	.708	-287.5
900	1.3171		384	.2931	158	.710	-317.1
800	1.3271		353	.2862	142	.713	-346.1
700	1.3382		321	.2792	125	.716	-374.3
600	1.3499		287	.2722	109	.719	-401.9
500	1.3614	↓	251	.2657	92	.723	-428.8
[a]400	1.2003	30.385	219	.2507	76	.717	-479.7
[a]300	1.2489	32.246	181	.2393	61	.706	-528.0

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IX. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 40 ATMOSPHERES

(e) Fuel-air ratio, 0.05

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1860	27.704	844×10^{-6}	0.5365	763×10^{-6}	0.593	269.4
2700	1.1946	27.788	822	.4952	664	.613	217.9
2600	1.2039	27.852	800	.4594	582	.631	170.2
2500	1.2135	27.897	777	.4298	516	.647	125.8
2400	1.2226	27.929	755	.4064	465	.660	84.0
2300	1.2309	27.950	732	.3886	424	.671	44.3
2200	1.2380	27.963	709	.3753	392	.678	6.2
2100	1.2442	27.972	686	.3652	366	.684	-30.8
2000	1.2496	27.977	662	.3574	344	.688	-66.9
1900	1.2545	27.980	639	.3511	325	.691	-102.4
1800	1.2591	27.981	615	.3457	307	.693	-137.2
1700	1.2635	27.982	591	.3407	290	.695	-171.5
1600	1.2680	27.983	566	.3361	273	.697	-205.3
1500	1.2727	↓	542	.3314	257	.698	-238.7
1400	1.2777	↓	517	.3267	241	.700	-271.6
1300	1.2831	↓	491	.3219	225	.702	-304.1
1200	1.2890	↓	465	.3167	209	.704	-336.0
1100	1.2955	↓	438	.3113	193	.707	-367.4
1000	1.3028	↓	410	.3055	177	.709	-398.2
900	1.3115	↓	381	.2990	160	.712	-428.5
800	1.3215	↓	350	.2919	143	.715	-458.0
700	1.3326	↓	318	.2845	126	.718	-486.8
600	1.3444	↓	284	.2772	109	.722	-514.9
500	1.3561	↓	248	.2704	92	.727	-542.3
[a]400	1.1915	31.235	218	.2508	76	.718	-604.4
[a]300	1.2279	33.148	181	.2391	61	.706	-653.7

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IX. - Continued. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 40 ATMOSPHERES

(f) Fuel-air ratio, 0.06

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1770	27.369	845×10^{-6}	0.5901	838×10^{-6}	0.595	197.1
2700	1.1833	27.480	823	.5494	738	.613	140.2
2600	1.1908	27.571	801	.5115	653	.628	87.2
2500	1.1992	27.642	779	.4773	580	.641	37.8
2400	1.2083	27.697	756	.4471	519	.651	-8.4
2300	1.2179	27.737	733	.4210	468	.660	-51.8
2200	1.2274	27.765	710	.3991	425	.667	-92.8
2100	1.2364	27.784	687	.3815	388	.674	-131.8
2000	1.2443	27.794	663	.3680	358	.681	-169.2
1900	1.2507	27.800	639	.3584	334	.686	-205.5
1800	1.2559	27.803	615	.3516	313	.690	-241.0
1700	1.2603	27.804	591	.3464	295	.693	-275.9
1600	1.2644	27.805	566	.3419	278	.696	-310.3
1500	1.2687	↓	541	.3375	262	.698	-344.3
1400	1.2732		515	.3331	245	.700	-377.8
1300	1.2783		489	.3283	229	.702	-410.9
1200	1.2839		463	.3232	212	.705	-443.4
1100	1.2903		436	.3176	196	.707	-475.5
1000	1.2976		408	.3116	179	.710	-506.9
900	1.3063		378	.3048	162	.713	-537.8
800	1.3163		347	.2974	144	.716	-567.9
700	1.3274		315	.2897	127	.720	-597.2
600	1.3392		280	.2821	109	.725	-625.8
500	1.3511		244	.2750	92	.731	-653.7
[a]400	1.1829	32.116	217	.2509	76	.719	-726.7
[a]300	1.2095	34.083	180	.2388	61	.706	-777.0

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

TABLE IX. - Concluded. THERMODYNAMIC AND TRANSPORT PROPERTIES OF THE COMBUSTION PRODUCTS OF NATURAL GAS AND AIR AT 40 ATMOSPHERES

(g) Fuel-air ratio, 0.06074 (stoichiometric)

Temperature, T, K	Isentropic exponent, γ	Molecular weight, m	Viscosity, μ, g/(cm)(sec)	Specific heat at constant pressure, c_p, cal/(g)(K)	Thermal conductivity, k, cal/(cm)(sec)(K)	Prandtl number, Pr	Enthalpy, h, cal/g
2800	1.1769	27.335	845×10^{-6}	0.5916	838×10^{-6}	0.597	193.6
2700	1.1831	27.446	823	.5509	737	.615	136.5
2600	1.1905	27.537	801	.5134	652	.631	83.4
2500	1.1987	27.609	779	.4796	579	.645	33.7
2400	1.2075	27.665	756	.4500	519	.656	-12.7
2300	1.2165	27.707	733	.4248	469	.665	-56.4
2200	1.2253	27.737	710	.4040	427	.672	-97.8
2100	1.2336	27.758	687	.3871	392	.678	-137.3
2000	1.2412	27.772	663	.3738	363	.683	-175.3
1900	1.2478	27.781	639	.3634	338	.687	-212.2
1800	1.2536	27.786	615	.3552	317	.690	-248.1
1700	1.2588	27.790	590	.3487	297	.693	-283.3
1600	1.2636	27.791	566	.3432	279	.695	-317.9
1500	1.2682	27.792	541	.3383	262	.697	-351.9
1400	1.2729	↓	515	.3336	246	.700	-385.5
1300	1.2780	↓	489	.3287	229	.702	-418.6
1200	1.2837	↓	463	.3235	212	.705	-451.3
1100	1.2900	27.793	435	.3180	196	.707	-483.3
1000	1.2973	↓	407	.3120	179	.710	-514.9
900	1.3059	↓	378	.3052	162	.713	-545.7
800	1.3160	↓	347	.2978	144	.716	-575.9
700	1.3271	↓	314	.2901	127	.720	-605.3
600	1.3389	↓	280	.2825	109	.725	-633.9
500	1.3508	↓	243	.2753	92	.731	-661.8
[a]400	1.1823	32.182	217	.2510	76	.719	-735.6
[a]300	1.2083	34.153	180	.2388	61	.706	-786.0

[a]Properties at this temperature reflect the effect of the condensation of water from the combustion products.

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